

Dec. 9, 1947.

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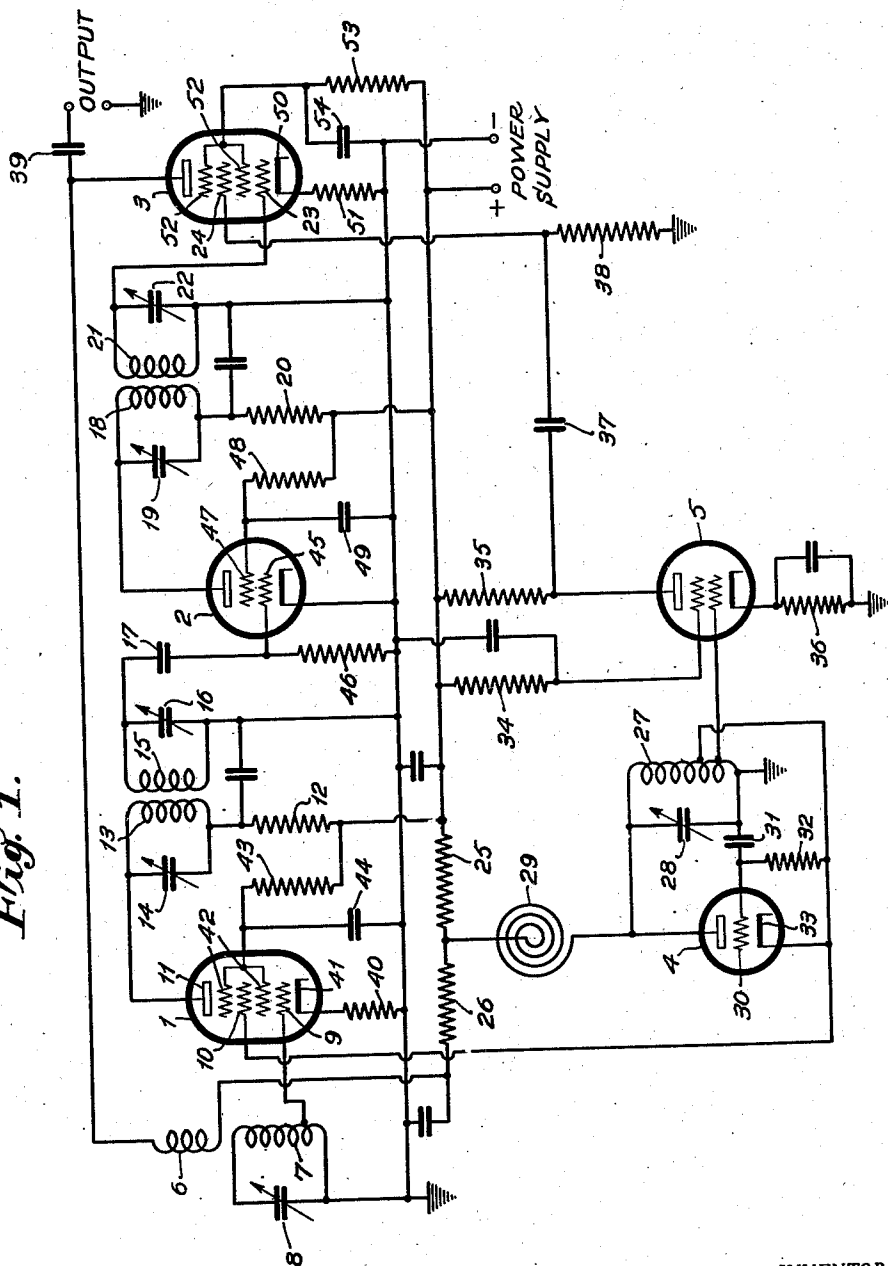
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OSCILLATOR WITH BEAT FREQUENCY STABILIZATION

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4 Sheets-Sheet 1

Fig. 1.



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4 Sheets-Sheet 2

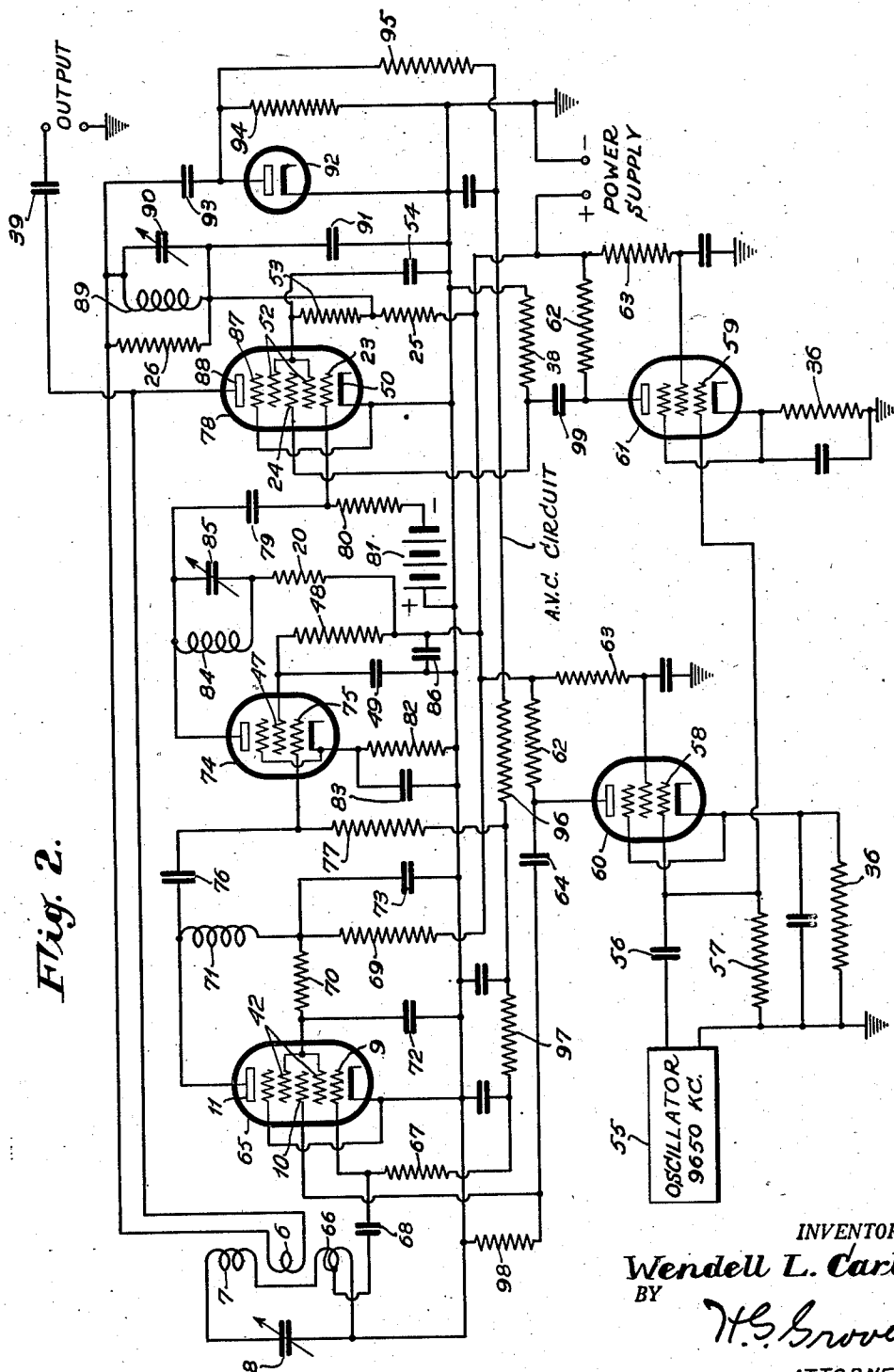


Fig. 2.

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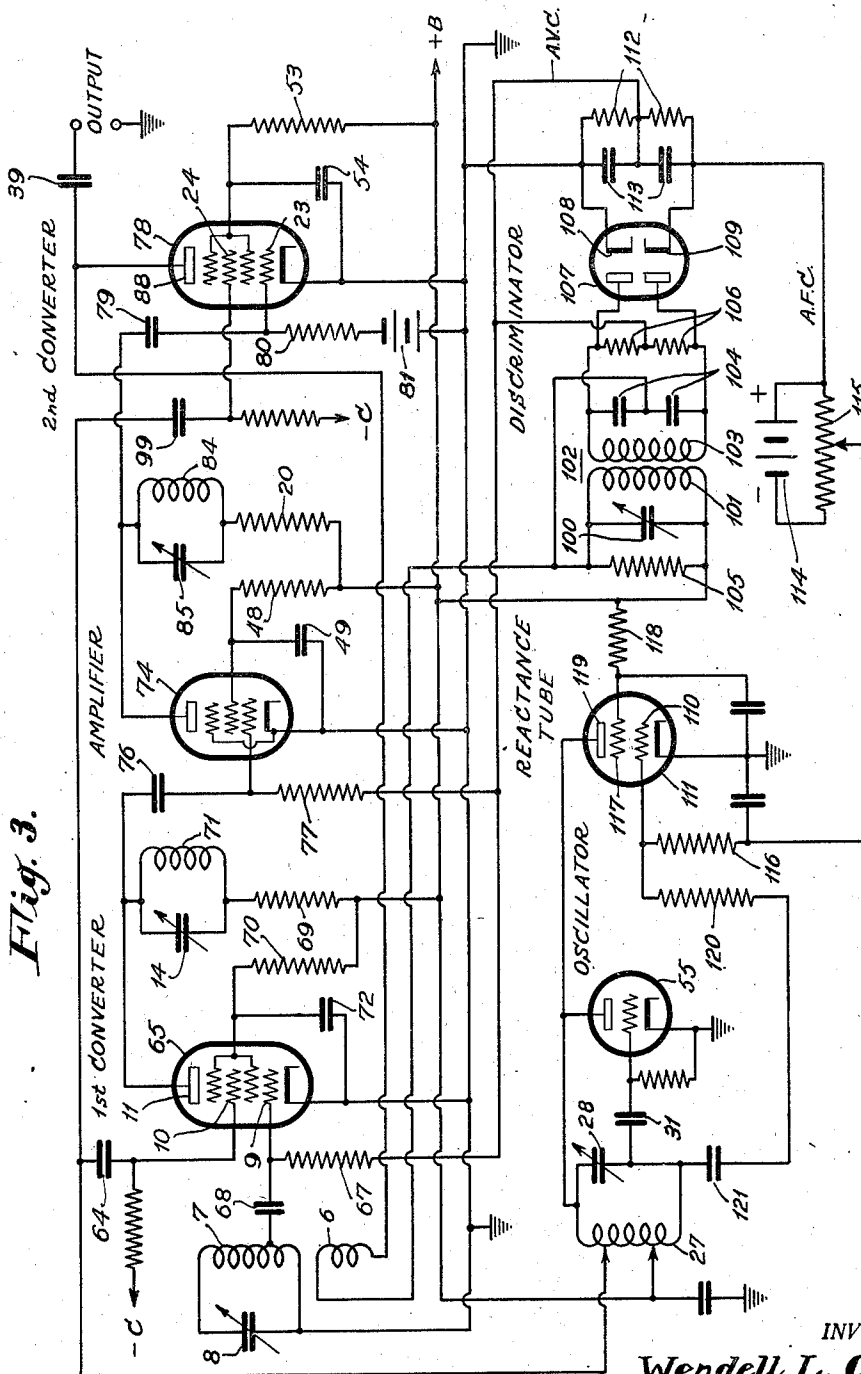
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4 Sheets-Sheet 3



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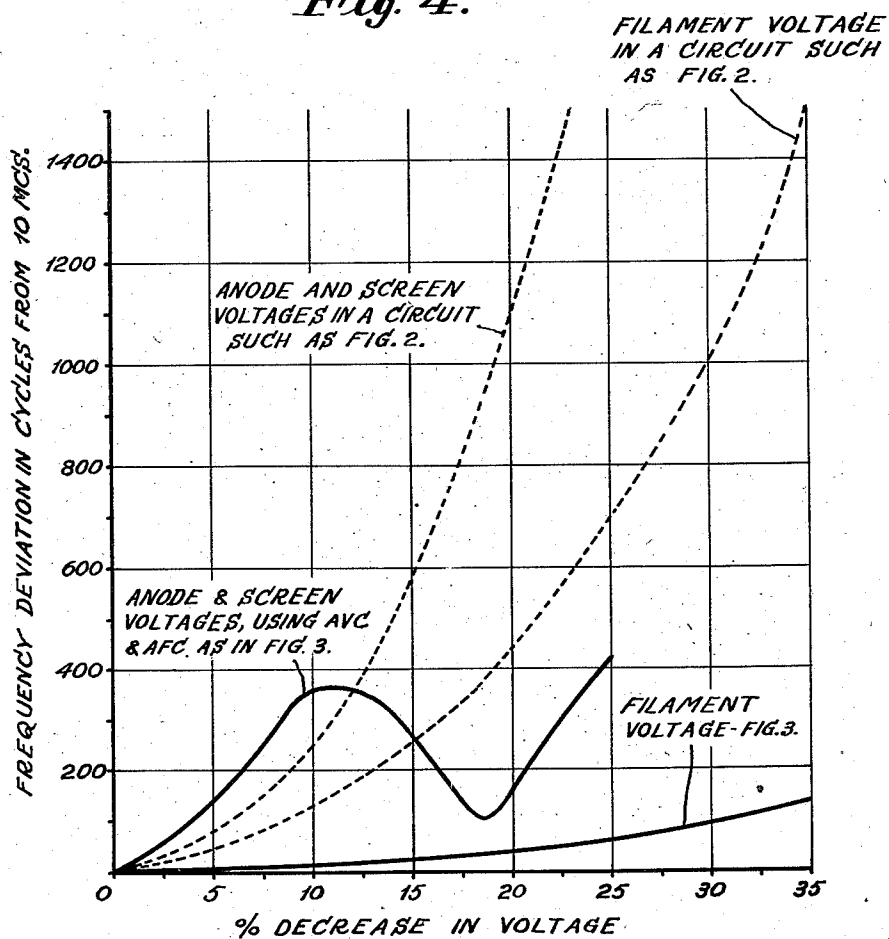
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OSCILLATOR WITH BEAT FREQUENCY STABILIZATION

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4 Sheets-Sheet 4

Fig. 4.



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OSCILLATOR WITH BEAT FREQUENCY
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Application October 21, 1943, Serial No. 507,126

9 Claims. (Cl. 250—36)

1

This invention relates to multiple tube oscillators and more particularly to systems for stabilizing the frequency of an oscillator without the aid of crystal control.

The causes of instability in the frequency of oscillators are primarily temperature and humidity changes, load changes, and voltage fluctuations. The effect of changing load, and the effect of capacity and inductance varying with temperature, may be minimized by good design. Thus, the remaining causes of frequency instability are all concerned with the oscillator tube itself. For example, a fluctuation in supply voltages will change the tube resistance and tube capacities which naturally affect the frequency. A further undesirable frequency change may result when the oscillator tube is replaced, if the new tube has different inter-element capacities. Also, the frequency may vary with time as the tube warms up.

Since changes in tube constants contribute so largely to frequency instability, it seems desirable to devise circuits in which the frequency will be more nearly independent of the tube constants. The most direct way of approaching this condition is to couple the tube weakly to the tuned circuit or to use a low L/C ratio. The phrase "to couple weakly to" is used to signify tapping the tube across a low impedance portion of the tuned circuit rather than a loosening of the coupling between fixed reactive circuit elements.

The degree to which the coupling can be reduced is limited by the mutual conductance of the oscillator tube. Obviously, greater frequency stability would result if tubes of higher mutual conductance were available, since the effect of the oscillator tube on the tuned circuit could be more nearly eliminated by the expedient of reduced coupling. If, however, the gain of the oscillator tube could be supplemented by means of an amplifier then very loose coupling to the frequency determining circuit could be used. Unfortunately, the use of looser coupling results in no increase in frequency stability if phase shifts occur elsewhere in the circuit, because such phase shifts must be cancelled by a contrary phase shift in the tuned circuit, which can only be obtained by a change in frequency. Thus, it is evident that the use of an amplifier at the same frequency has little or no advantage.

The advantages of amplification with minimum phase shift can be obtained by use of a low frequency amplifier. Two heterodyne detectors are required to accomplish the two necessary fre-

2

quency conversions. For heterodyning, the same local oscillator is used in both detectors. The frequency of this oscillator differs from the desired frequency by the frequency of the amplifier.

It is an object of my invention to provide an oscillator tunable over a wide range of frequencies and having great frequency stability.

Another object of my invention is to provide an oscillator having a multiple tube circuit which operates on the heterodyne principle for producing interstage frequency compensation.

Still another object of my invention is to provide a multiple tube oscillator having feedback means between two of its stages and an automatic volume control circuit arrangement in addition to other means for frequency stabilization.

Another object of my invention is to provide a multiple tube oscillator of the type indicated in the preceding paragraph and also characterized by the provision of an automatic frequency control device associated with the oscillatory circuit of one of the tubes.

The foregoing and other objects of my invention will be more clearly understood in view of the following description taken in connection with the accompanying drawings, in which:

Fig. 1 shows a multiple tube oscillator circuit arrangement embodying the fundamental features of my invention;

Fig. 2 shows another embodiment of my invention in which features of automatic volume control are added;

Fig. 3 shows still another embodiment of my invention in which automatic frequency control means are added to the elements in combination as shown in Fig. 2; and

Fig. 4 shows a chart of frequency deviation in relation to percentages of decrease in the anode and screen supply voltages from a predetermined value.

Referring first to Fig. 1, I show therein an oscillatory circuit which comprises five discharge tubes 1, 2, 3, 4, and 5 and associated circuit connections. Oscillations of a desired frequency are generated in the tube 3 in the anode circuit of which is a feedback inductance 6 loosely coupled to the inductance 7 in a parallel tuned circuit of high frequency stability. The parallel tuning is accomplished by means of a variable capacitor 8. The coupling between the inductances 6 and 7 is preferably made quite loose in order to minimize the phase shift of the oscillations in the feedback circuit. For the same reason, loose coupling is provided between the tuned circuit 7, 8

3

and control grid 9 in the converter tube 1. This condition is obtained by tapping the coil 7 at a point quite close to its grounded terminal.

Tube 1 is also controlled through its grid 10 by oscillations generated in the tube 4 at a relatively lower frequency. Tube 1, therefore, operates to heterodyne the higher and lower frequencies and to deliver an output at a difference frequency to which its output circuit is tuned. The anode 11 is, therefore, connected to the plus terminal of a power supply through a resistive impedance 12 and the inductance 13 of a tuned circuit. Parallel tuning is obtained by means of the adjustable capacitor 14.

The inductance 13 constitutes a transformer primary, the secondary 15 of which forms part of another parallel tuned circuit inclusive of adjustable capacitor 16. The tuned circuit 15, 16 is coupled to the input circuit of tube 2 across capacitor 17.

In consequence of the loose coupling mentioned in the foregoing description, it is necessary to amplify the output from tube 1. Amplification is obtained, therefore, by tube 2 and the output circuit of this tube is also tuned to an intermediate frequency not greatly different from that of the tuned circuits 13, 14 and 15, 16. The output circuit of tube 2 includes parallel resonant inductance 18 and capacitance 19. The anode supply voltage is delivered through a resistor 20. The inductance 18 forms the primary of a transformer, the secondary 21 of which is parallel-tuned by capacitor 22. The tuned circuit 21, 22 is disposed between a first grid 23 in tube 3 and ground. Tube 3 is also controlled by means of its grid 24 in accordance with oscillations from the generator 4 but by way of a buffer amplifier tube 5. These are high frequency oscillations of a frequency less than the desired output frequency by the intermediate frequency which is delivered through tube 2. Tube 3, therefore, acts as a second converter for heterodyning the frequencies impressed upon its grids 23 and 24. The output from tube 3 is both a sum and a difference frequency, but the sum frequency alone is utilized in the feedback circuit which includes the inductance 6. Anode potential is supplied to tube 3 through resistors 25 and 26.

Tube 4 represents any suitable oscillator, but for illustrative purposes, it is here shown as of the well-known Hartley type having its cathode connected to an intermediate point on the parallel-tuned inductance 27. Inductance 27 is disposed in parallel-tuned relation to the adjustable capacitor 28. Anode potential is supplied through resistor 25 and a choke 29. The control grid 30 is maintained at ground potential for alternating current, being coupled to ground across capacitor 31. A grid leak resistor 32 is provided in connection between the grid 30 and the cathode 33.

The buffer stage previously mentioned as including tube 5 has its control grid connected to a point of low alternating potential on the inductance 27. The screen grid of tube 5 is supplied with a suitable potential across resistor 34. Anode potential is also supplied across resistor 35. The output circuit of tube 5 includes cathode resistor 36 which is grounded at the lower end. The anode is coupled across capacitor 37 to grid 24 in the converter tube 3. The control potentials for grid 24 are developed across a resistor 38 which is connected between one electrode of capacitor 37 and ground.

A cathode resistor 40 is shown between the cathode 41 in tube 1 and ground. The second and

4

fourth grids 42 in tube 1 both act as screens and are supplied with screen grid potential across resistor 43. Grids 42 are also coupled to ground across capacitor 44.

In tube 2, the control grid 45 is connected to ground across grid leak resistor 46. The screen grid 47 is supplied with suitable D. C. potential across resistor 48 and this grid is also coupled to ground across capacitor 49.

In tube 3, cathode 50 is connected to ground across a cathode resistor 51, while its second and fourth grids 52, serving as screens, are supplied with suitable D. C. potential across resistor 53 and these grids 52 are coupled to ground across capacitor 54.

The operation of the circuit arrangement of Fig. 1 will be more readily understood by explaining the same in reference to a specific selection of frequencies to be used in the different portions of the circuit. These frequencies, however, are to be understood as chosen merely for purposes of illustration and the invention itself is not restricted to the use of any particular frequency. If the frequency of the oscillator 4 is set at 9650 kc., the tank circuit 7, 8 may be tuned to 10,000 kc. Heterodyning of these two frequencies produces a difference-frequency output from tube 1 of 350 kc. Circuits 13, 14 and 15, 16 are very broadly tuned to 350 kc. Likewise circuits 18, 19 and 21, 22 are also broadly tuned to 350 kc. The broad tuning is for the purpose of minimizing phase shifting of the signal passing through the low frequency amplifier. Higher amplification can be obtained with a minimum of phase shift by amplifying at a substantially lower frequency than the desired output frequency.

A modification of the low frequency amplifier may consist of employing single resonant circuits instead of coupled circuits. Thus, for example, circuit 15, 16 may be omitted and the anode end of the tank circuit 14, 13 may be coupled directly to condenser 17. A similar change may be made in the circuit coupling tubes 2 and 3. In this case circuit 13, 14 is preferably tuned to about 400 kc. and circuit 18, 19 is tuned to about 300 kc. in the illustrative form as described. This arrangement minimizes phase variations in the low frequency current passing through the amplifier. Such variations are unavoidably accompanied by frequency drift and are due to small frequency variations in the oscillator associated with tube 4. At the main frequency of the amplifier, the coupling circuits, therefore, act like nearly pure reactances so that a change in mutual conductance or in tube capacity or a change in intermediate frequency produces very little phase shift. In an embodiment which has actually been constructed according to my invention, the extent to which the output frequency was found to be independent of the amplifier frequency is evidenced by the fact that a change in the local oscillator frequency of 28 kilocycles in tube 4 produced a change of only two kilocycles in the output frequency from tube 3.

To summarize the operation of Fig. 1, the desired output frequency is derived from the second converter tube 3 by coupling its output circuit to a utilization device through capacitor 39. Tube 3 derives its control from the intermediate frequency amplifier 2 (which delivers a low intermediate frequency to the grid 23), and from oscillations produced by the oscillator 4, which are transferred through the buffer amplifier stage 5 to the grid 24. Heterodyning takes place in tube 3 in such manner as to deliver a sum-frequency

5

to the feedback circuit, the inductance 6 of which is coupled to the tuned resonant tank circuit 7, 8. The latter is a circuit which is isolated so far as possible from other components of the entire circuit arrangement in order that its frequency stability may be maintained. Its loose coupling with the grid 9 in tube 1, however, enables this tube to act as a first converter, where oscillations of the frequency generated by tube 4 are delivered to grid 10. The intermediate frequency which, in fact, is a difference-frequency output from tube 1 is amplified in tube 2 and utilized in the second converter tube 3.

Referring now to Fig. 2, I show therein a modified circuit arrangement which, however, follows generally the principles set forth in respect to the circuit arrangement of Fig. 1. Additional features are provided which include an automatic volume control circuit for assisting in the maintenance of frequency stability.

A conventional oscillator circuit 55 may be considered as a substitute for the electronic oscillator 4 in Fig. 1. The output from oscillator 55 is coupled across the capacitor 56 to one end of a load resistor 57, the other end being grounded. The A. C. potential developed across resistor 57 is applied to control grids 58 and 59 in two buffer amplifier tubes 60 and 61 respectively. These tubes are preferably of a conventional pentode type having three grids, a cathode, and an anode. Anode potential is supplied from the direct current power supply (so labelled) across the resistor 62. Screen grid potential is also supplied from the same source across resistor 63. These connections are the same for both tubes 60 and 61.

Output potential from tube 60 is coupled across capacitor 64 to a third grid 10 in a first converter tube 65 corresponding to tube 1 in Fig. 1. This coupling develops control potentials across the grid leak resistor 98. Tube 65 is preferably of the heptode type wherein the first and third grids are used for control purposes, the second and fourth grids are screens and the fifth grid, connected to the cathode, serves as a suppressor. The grid 9, nearest the cathode, is preferably controlled by A. C. potentials derived from the parallel-resonant circuit consisting of inductance 7 and adjustable capacitor 8. One end of this parallel-resonant circuit is grounded, and a tap 66 for the utilization of oscillatory potentials is made near the grounded end of the resonant circuit in order to supply a necessary control voltage across the grid leak resistor 67 for application to the grid 9 in tube 65. A coupling for this circuit is provided by capacitor 68. The screen grids 42 in tube 65 are maintained at suitable D. C. potential derived from the power supply and fed across resistors 69 and 70. Through resistor 69 D. C. potential is also carried to the anode 11 in tube 65, where a tuning inductance 71 is series-connected to the anode circuit. Capacitor 72 serves to bypass alternating current potentials from the screens 42 to ground. Capacitor 73 bypasses to ground any alternating potentials that may appear at the junction between resistor 69 and inductance 71.

An intermediate frequency amplifier stage comprises tube 74 which occupies the position of tube 2 in Fig. 1. Tube 74 is preferably of the pentode type. Its screen grid 47 is fed with D. C. potential across resistor 43, and A. C. potentials appearing on the screen 47 are bypassed to ground across capacitor 49. The cathode of tube 74 is provided with a cathode resistor 82, in parallel

6

with which is a bypass capacitor 83. The output circuit for tube 74 includes a parallel-resonant tank consisting of inductance 84 and tuning condenser 85. Bypass condenser 86 couples a point of zero potential swing on the resonant circuit 84, 85 to ground. The control grid 75 receives potentials from the output circuit of tube 65 by virtue of the coupling capacitor 76. Control potentials are developed across the grid leak resistor 77, the latter being connected to a suitable point on an AVC circuit, so labelled. Both of the tubes 65 and 74 are subject to automatic volume control where the AVC potential is derived from the rectification of a component of output energy from a second converter tube 78. This tube occupies the position of tube 3 in Fig. 1. It is, however, preferably of the heptode type wherein the first grid 23 receives its control potentials by virtue of a coupling capacitor 79 connected to the anode in tube 74 and also to a grid leak resistor 80.

A suitable negative bias is applied to grid 23 by means of a grid biasing source 81, the positive terminal of which is grounded, while its negative terminal is connected to one end of the grid leak resistor 80.

Tube 78 is preferably provided with a suppressor grid 87, but in other respects, its construction includes the same electrodes as are shown in tube 3 (Fig. 1). The output circuit for tube 78 may be traced from the anode 88 through the feedback coil 6 and thence through resistors 26 and 25 to the positive terminal of the power supply. The negative terminal of this power supply is connected to the grounded cathode 50. Screen grid potential is applied to the screens 52 across resistors 25 and 53.

A parallel-resonant circuit consisting of inductance 89 and capacitor 90 is disposed in shunt with resistor 26, this resonant circuit being tuned to the frequency which is to be utilized as output from the entire circuit arrangement. The output to a utilization device is preferably coupled to the anode 88 across capacitor 39. The voltage swing developed in the resonant circuit 89, 90 appears at the upper end as shown in the diagram, the lower end being maintained at A. C. ground potential by virtue of the bypass capacitor 91, one terminal of which is grounded.

AVC potentials are developed by means of a rectifier tube 92 to the anode of which an output component derived from the feedback circuit is applied across capacitor 93 and resistor 94. The cathode in tube 92 is maintained at ground potential. The time constant value of elements 93 and 94 is made such as to provide a suitable delay action in the AVC circuit. This circuit includes series resistors 95, 96, and 97, where resistors 95 and 96 are common to the input circuits of tubes 65 and 74, and resistor 97 feeds AVC potential through resistor 67 exclusively to the grid 9 in tube 65.

The basic operation of the circuit arrangement shown in Fig. 2 may be understood by reference to the foregoing explanation applicable to Fig. 1. The same frequencies may also be considered by way of illustration. That is to say, if the oscillator 55 generates a frequency of 9,650 kc. and if the resonant circuit 7, 8 is tuned to 10,000 kc., then a difference-frequency of 350 kc. is obtained from the heterodyne action in tube 65. The tuned input circuit for the amplifier tube 74 is preferably adjusted to a value of substantially 400 kc., whereas its output circuit is preferably tuned to substantially 300 kc. A desired band-

pass characteristic of the amplifier tube 74 is thus obtained for favoring the amplification of the difference-frequency at 350 kc. which is applied as one component of the input energy for the second converter tube 78. The other frequency applied to this tube at the third grid 24 is derived indirectly from the oscillator 55, controlling, as it does, the buffer amplifier tube 61. The control potentials from the anode of tube 61 are coupled across capacitor 99 directly to grid 24 in tube 78.

The AVC circuit operates upon the first converter tube grid 9 and the intermediate frequency tube grid 75 in such manner that no grid current is allowed to flow in the second converter tube grid circuit including grid 23 and its grid leak resistor 80.

In adjusting the parameters of the circuit arrangement of Fig. 2 for optimum operating conditions, it is advisable to obtain a Q which is as high as possible in the output tuned circuit. The achievement of this aim results in greater stability of the resulting output frequency since it facilitates the use of very loose coupling with respect to the feedback coil 6 and also to the input circuit of tube 65. In a specific embodiment of the invention which was constructed in accordance with Fig. 2, the Q of the tuned circuit 7, 8 was designed to be approximately 150, being limited to a readily obtainable value at 10 megacycles when the diameter of the coil 7 was fixed at substantially $\frac{1}{2}$ inch and the coil itself was wound on a standard RCA "Styrol" form.

The advantages of minimizing the grid current in such places as the second converter tube 78 by means of automatic bias control may be well appreciated by those acquainted with the prior art in connection with frequency stabilization of oscillators. It is also a well-known fact that appreciable improvement in frequency stability results from the reduction of the grid current to a small value. Consequently, in carrying out my invention, still further frequency stability is accomplished by the elimination of grid current. Hence, the grid bias is preferably to be set in accordance with the oscillation amplitude by means of an automatic volume control amplifier.

In order to increase further the frequency stability in a multi-stage oscillator, I have found it advantageous to incorporate automatic frequency control with the double heterodyne principle as heretofore described. This may be accomplished, for example, by utilizing the system which is illustratively shown in the circuit diagram of Fig. 3.

Referring to Fig. 3, I show therein the essential components of a double heterodyne oscillator having automatic volume and frequency control. The circuit arrangement is quite similar to that which is shown in Fig. 2 but with a discriminator stage and a reactance tube added for the purpose of exercising frequency control over the oscillator which is to deliver a lower-than-wanted frequency for heterodyning purposes.

The resonant circuit 7, 8 is used in the same relation to a first converter tube 65 as is shown in Fig. 2. The same oscillator 55 is shown in both figures. Other elements bear corresponding reference numbers in the two figures and are similarly disposed in the circuit arrangement. These elements include the I. F. amplifier tube 74, the second converter tube 78, and associated circuits.

The output circuit from the second converter tube 78 may be traced from its anode 88 through

the feedback coil 6 and thence to one terminal of a parallel-tuned circuit comprising a capacitor 100 and an inductance 101. This inductance forms the primary winding of a transformer 102, the secondary 103 of which is the inductance element of another parallel-tuned circuit wherein the capacitance is composed of two series-connected condensers 104. The intercoupled resonant circuits 100, 101 and 103, 104 are both tuned to the I. F. frequency which is applied to the control grid 23 in tube 78. In shunt with the tuned circuit 100, 101 is a resistor 105 and another resistor 106 is in shunt with the resonant circuit 103, 104.

Anode potential for the second converter tube 78 is supplied from the positive terminal of the direct current source through resistor 105 in parallel with the inductance 101, and thence through the feedback coil 6 to the anode 88.

The terminals of the resonant circuit 103, 104 are connected to the two anodes respectively of a twin diode tube 107. The two cathodes of this twin diode are separate but cathode 108 is connected to ground while cathode 109 is connected to an automatic frequency control circuit for supplying suitable control bias to the first grid 110 in a reactance tube 111. The cathodes 108 and 109 are interconnected through resistors 112 and are also intercoupled by series capacitors 113.

Interposed between the cathode 109 in the twin diode 107 and the input circuit for the reactance tube 111 is a grid bias adjusting device comprising an independent direct current source 114, the terminals of which are connected respectively to the two ends of a potentiometer 115. An adjustable tap on this potentiometer is connected to the grid 110 of the reactance tube 111 through a grid leak resistor 116.

The reactance tube 111 possesses a screen grid 117 on which suitable screen grid potential is impressed through resistor 118. The anode 119 is connected to the anode in the oscillator tube 55.

Alternating current control potentials are supplied to the grid 110 in the reactance tube by way of resistor 120 and capacitor 121. These potentials are derived from the resonant circuit 27, 28 which is associated with the oscillator tube 55.

In general, the circuit parameters for the different tube stages are conventional and require no further description in view of the detailed descriptions which have been supplied above in reference to Figs. 1 and 2. The discriminator circuit arrangement which includes the transformer 102 and its associated tuning devices and also the twin diode rectifier 107 constitute a discriminator circuit arrangement of conventional type. A similar discriminator is described in my Patent No. 2,243,414 which issued May 27, 1941. Other discriminators are well known in the art and may be adopted in place of that which is herein shown without departing from the spirit and scope of the instant invention. This discriminator is arranged to vary the grid bias on the reactance tube 111 in accordance with frequency variations appearing in the output of the intermediate frequency amplifier 74.

The operation of the circuit arrangement shown in Fig. 3 will be understood in the main in view of the preceding descriptions of the embodiments shown in Figs. 1 and 2 when supplemented by the specific description of the added feature of the frequency control circuit for the oscillator 55. To summarize, however, it will be seen that if the desired output frequency is to be that to which the resonant circuit 7, 8 is tuned, and if the fre-

quency of output from the oscillator 55 is somewhat lower than the wanted frequency, then the first converter tube 65 will serve to deliver an intermediate frequency, say of 350 kc., as in the illustration given with respect to Figs. 1 and 2. In the second converter stage which includes the tube 78 and its circuit components, the output from the I. F. amplifier 74 is applied to grid 23 while the output from the oscillator 55 is applied to the third grid 24. The output circuit which includes the feedback coil 6, therefore, has three principal frequency components, namely, the frequency of the oscillator 55, the I. F. frequency, and the sum of these two frequencies, the latter being that to which the resonant circuit 7, 8 is tuned. Thus the sum-frequency is also available for utilization purposes as by coupling across the capacitor 39.

It will be recalled that the resonant circuit which includes the windings of the transformer 102 are both tuned to the I. F. frequency. The phase shift in the intermediate frequency amplifier is preferably minimized by the employment of suitable resistance loading in the associated circuits. To obtain a small amount of coupling to the input circuit of the second converter while maintaining the high Q which is desired, an overall gain of approximately 7,000 is preferably chosen.

The AVC voltage derived from the discriminator in Fig. 3 is developed between ground and the mid-tap on the resistive element 106. This voltage also appears as a potential drop across the upper half of resistor 112 and is negative with respect to ground since the cathode 108 is maintained at ground potential. The automatic frequency control voltage is developed positively with respect to ground in accordance with the rectification which takes place in the lower half of the twin diode tube 107, the cathode 109 of which becomes more and more positive as the amplitude of the oscillations increases. This tends, therefore, to apply a more positive bias to the grid 110 in the reactance tube 111, thereby to reduce the impedance of the reactance tube 11. As a result the anode voltage in tubes 111 and 55 is reduced to compensate for such frequency increase in the output from oscillator 55 as may be attributed to a voltage increase in the D. C. supply source.

The slopes of the reactance tube and discriminator characteristics are capable of such determination that a 100-cycle change in intermediate frequency produces a 10-kilocycle change in a 10-megacycle local oscillator frequency, i. e., a control ratio of 100. The measurement of the frequency change in the local oscillator produced by the addition of a small shunt capacitor to the oscillator tank, conditions being compared with and without the feedback circuit present, shows that the local oscillator frequency may be changed in the ratio 1/50 by the presence of the feedback circuit.

Fig. 4 shows the degree of frequency stabilization which is possible of attainment in carrying out my invention. The horizontal scale shows percentages of voltage decrease from normal, in respect to anode, screen grid, and filament voltages. The frequency deviation in cycles from a nominal value of 10 megacycles is indicated on the vertical scale. The full-line curves show the coordination of voltage vs. frequency deviation when utilizing automatic volume control and also automatic frequency control as described in reference to Fig. 3. The curves shown in broken lines give corresponding values of frequency de-

viation when automatic volume control alone is used in accordance with the embodiment shown and described in reference to Fig. 2. It is apparent from observation of Fig. 4 that a high degree of frequency stability is obtainable in multi-tube oscillators when operating in a frequency range such as to include 10 megacycles, for example, by means of multi-tube feedback circuits which employ either the double heterodyne scheme with automatic volume control alone or by means of such a system with automatic frequency control added.

While my invention is described in the foregoing and illustrated in the drawings so as to enable anyone skilled in the art to follow my teachings and to adopt advantageous practices in the design of stabilized multi-tube oscillators, I wish it to be understood that the invention itself is by no means limited to the specific form and construction of the circuit arrangements so described and illustrated.

I claim:

1. In an oscillation generator having a plurality of intercoupled stages, including two mixer tube stages and an intervening difference-frequency amplifier stage, a resonant circuit disposed in loosely coupled relation to the input of the first of said mixer tube stages, a source of oscillations the frequency of which when heterodyned with oscillations from said resonant circuit produces said difference-frequency, means for feeding energy from said oscillation source to both of said mixer tube stages thereby to cause heterodyning in one case with the frequency of said resonant circuit, and in the other case with output from said amplifier stage, and a feedback circuit originating at said second mixer tube stage and loosely coupled to said resonant circuit, said feedback circuit being arranged to control the generated oscillations by a sum-frequency component of output from the second of said mixer tube stages.

2. A circuit arrangement according to claim 1 and including parallel-tuned input and output circuits for said amplifier stage, said parallel-tuned circuits being resonant in one case to a higher frequency and in the other case to a lower frequency than said difference-frequency.

3. A circuit arrangement according to claim 1 and including a volume control device operative upon the gain in the first mixer tube stage and in said amplifier stage in response to rectified output energy from said second mixer tube stage.

4. A circuit arrangement according to claim 1 and including means for causing the output from said oscillation source to be frequency-controlled by output from said second mixer tube stage.

5. In a multi-tube oscillation generator, an electronic oscillator tuned to a frequency below that which is wanted for utilization, a resonant circuit tuned to that wanted frequency, a cascade arrangement of two converter tube stages and an intervening amplifier tube stage, the first of said converter tube stages having input circuit means for mixing energy components derived from said oscillator and from said resonant circuit, said amplifier stage having a filter band-pass characteristic which accepts the difference-frequency derived from heterodyning output energy from said electronic oscillator with oscillations from said resonant circuit, means effective in the second of said converter tube stages for mixing two frequencies, namely, that of said electronic oscillator and said difference-frequency passed by the amplifier stage, thereby to deliver a

11

sum-frequency substantially corresponding to the frequency of said resonant circuit, and feedback means loosely coupling the output from the second converter tube stage to said resonant circuit.

6. A multi-tube oscillation generator comprising a first converter stage, a tuned resonant circuit coupled to the input side of said converter stage, an external source of oscillations the output from which is fed to said converter stage and is of a different frequency in relation to that to which said resonant circuit is tuned, an output circuit for said converter stage having a filter-pass characteristic which accepts a difference-frequency component of the heterodyned output energy from said converter stage, an amplifier stage the input circuit of which is controlled by said component of heterodyned energy, an output circuit for said amplifier stage having a filter-pass characteristic which partially overlaps the frequency band of said converter stage output circuit, whereby said difference-frequency component also controls a subsequent stage, said subsequent stage being constituted as a second converter having control electrodes connected respectively to the output side of said amplifier stage and to said external source, said second converter having an output circuit which includes an inductance loosely coupled to said tuned resonant circuit, and means for utilizing in said second converter stage an amplified energy component of said external source of oscillations, whereby the useful output from said second converter is of a frequency corresponding substantially to that of said resonant circuit.

7. A multi-tube oscillation generator comprising a first and a second converter tube stage, an amplifier stage interposed between and in cascaded relation to said converter tube stages, said amplifier stage having input and output circuits which are tuned to frequencies one slightly above and one slightly below a difference-frequency component of output energy derived from the first converter, means including a resonant circuit and an external source of oscillations having different frequency characteristics for producing a heterodyne action in said first converter stage such as to cause the delivery of said difference-frequency output energy to said amplifier stage, means including a buffer amplifier interposed between the output circuit of said external source and the input to said second converter for mixing therein the frequency components of said external source and of said difference-frequency passed by the first said amplifier stage, a feed-

12

back device in the output circuit of said second converter coupled to said resonant circuit, and automatic volume control means controlled by rectified energy derived from said second converter and applied to the control grids of said first converter and the first said amplifier respectively.

8. A multi-tube oscillation generator comprising a first and a second converter tube stage, an amplifier stage interposed between and in cascaded relation to said converter tube stages, said amplifier stage having input and output circuits which are broadly tuned to a relatively low difference-frequency component of output energy derived from the first converter, means including a resonant circuit and an external source of oscillations having different frequency characteristics for producing a heterodyne action in said first converter stage such as to cause the delivery of said difference-frequency output energy to said amplifier stage, means including a buffer amplifier interposed between the output circuit of said external source and the input to said second converter for mixing therein the frequency components of said external source and of said difference-frequency passed by the first said amplifier stage, a feedback device in the output circuit of said second converter coupled to said resonant circuit, and automatic volume control means controlled by rectified energy derived from said second converter and applied to the control grids of said first converter and the first said amplifier respectively.

9. An oscillation generator according to claim 8 and including automatic frequency control means under control of output energy from said second converter stage and effectively applied to the stabilization of the output frequency of said external source.

WENDELL L. CARLSON.

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The following references are of record in the file of this patent:

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