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FREQUENCY CHANGER

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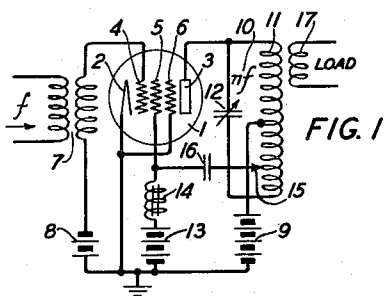


FIG. 1

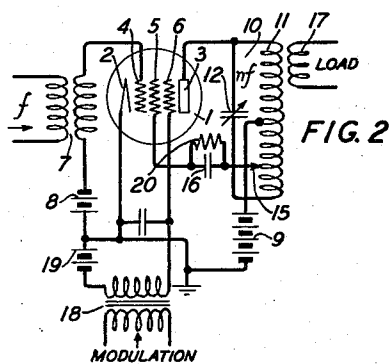


FIG. 2

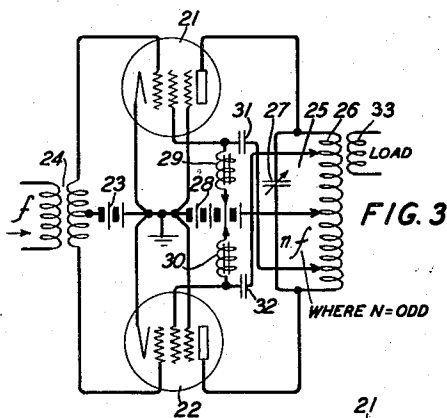


FIG. 3

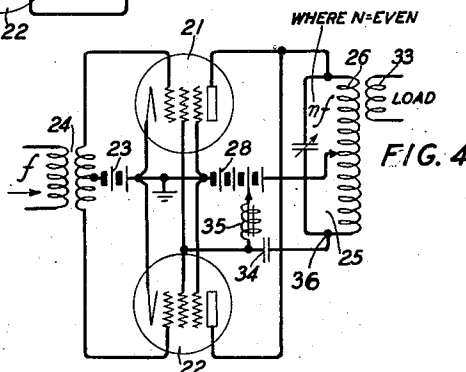


FIG. 4

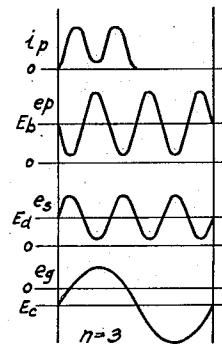


FIG. 5

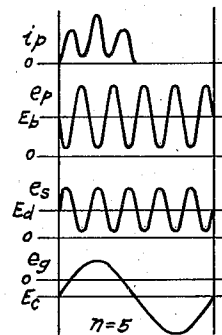


FIG. 6

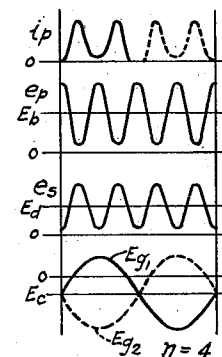


FIG. 7

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FREQUENCY CHANGER

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5 Claims. (Cl. 250—36)

The invention relates to frequency changers and particularly to frequency changers of the electron discharge tube type.

It is well known that efficient operation of an electron discharge device requires that the power dissipated at the plate electrode be small in proportion to the amount of power delivered to the output circuit of the device. Since the power dissipated at the plate is a product of the plate current and the plate voltage existing at the time it flows, averaged over a cycle, it is evident that the largest amount of plate current can be passed if it is made to flow at a time when the plate voltage is lowest.

In the usual vacuum tube frequency multiplier, the multiplier tube is excited by applying a voltage of the base frequency f to the input and the plate circuit is tuned by an anti-resonant circuit to the desired harmonic frequency nf . Efficient operation of such circuits makes necessary the use of a relatively large exciting voltage and a large negative bias on the control grid of the multiplier tube, so that the plate current will flow in very short pulses in order to make the harmonic content high, and the circuit will remain quiescent during the remainder of each cycle. If the plate circuit is tuned to the harmonic frequency nf the plate voltage is the product of the n^{th} harmonic component of the plate current and the impedance of the output circuit at the n^{th} harmonic frequency since an anti-resonant circuit has a high impedance to the frequency to which it is tuned and low impedance to all other frequencies.

Thus, for the case where the n^{th} harmonic is desired in such a circuit a pulse of energy will be produced in the output circuit only once every n cycles, limiting the harmonic power obtainable to approximately $1/n^{\text{th}}$ the fundamental power obtainable in a direct amplifier if space current is taken as the limiting factor in the tube. In addition, the plate circuit must provide "fly-wheel" action in the periods between pulses to maintain the voltage, and the harmonic power obtainable depends on this fly-wheel action which must be maintained. Obviously, as the harmonic n becomes larger, the fly-wheel action must be increased and the harmonic power generated is decreased.

It is an object of the present invention to produce economically waves of frequencies which are harmonics of a given base frequency and with greatly increased power at the higher harmonics over that obtainable with the vacuum tube frequency multipliers of the prior art.

This object is attained in the frequency changer circuit of the invention by the use of one or more multi-grid vacuum tubes and associated circuits arranged to produce a pulse of plate current every half-cycle or cycle of a frequency which is a desired harmonic of the base frequency. In a modification of the invention, the same apparatus employed for producing the above result is utilized simultaneously as a modulator.

The objects and advantages of the circuits of the invention will be better understood from the following detailed description thereof when read in connection with the accompanying drawing in which:

Figs. 1 to 4 show schematically frequency changer circuits embodying different modifications of the invention; and

Figs. 5, 6 and 7 show curves illustrating the operation of the circuits of the invention.

A frequency multiplier circuit in accordance with the invention is illustrated in Fig. 1. It comprises a single pentode vacuum tube 1 having the usual filament or cathode 2, a plate or anode 3, a control grid 4, a screen grid 5 and a suppressor grid 6. An input transformer 7 has a primary winding connected to an alternating current source (not shown) of the base frequency f to be multiplied and its secondary winding connected across the control grid 4 and cathode 2 of tube 1. The cathode 2 is supplied with heating current from any suitable source (not shown).

The control grid 4 is negatively biased with respect to the cathode 2 by the battery 8. The output circuit of tube 1 comprises in series between the cathode 2 and the plate 3, the plate battery 9 and the resonant circuit 10 comprising the inductance coil 11 and the variable condenser 12 in parallel. The screen grid 5 is positively biased with respect to the cathode 2 by battery 13 through choke coil 14, and is connected to a tap 15 on coil 11 of resonant circuit 10 through condenser 16. A load circuit is connected to the output of tube 1 by a coil 17 inductively coupled to the coil 11 of the resonant circuit 10.

In the operation of the circuit of Fig. 1, the exciting voltage of the base frequency f is impressed by input transformer 7 on the cathode-control grid circuit of tube 1. The negative bias on the control grid 4 is made such that space current flows from plate battery 9 through the tube 1 during approximately 180 degrees of each cycle of frequency f . The resonant circuit 10 is tuned to the desired harmonic frequency nf , and an alternating voltage of that frequency is fed from the tap 15 on coil 11 in resonant circuit 10

through condenser 16 to the screen grid 5, and is superposed on the fixed positive bias applied to the screen grid 5 from battery 13, 180 degrees out of phase with respect to the plate voltage.

5 The effect of this is to produce in the resonant circuit 10 in the output of tube 1, a pulse of plate current every cycle of the harmonic frequency nf during the positive half-cycle of the fundamental frequency f , the produced pulses being induced

10 in the coil 17 connected to the load circuit. The power in the wave of harmonic frequency thus produced in the load circuit will be much greater at the higher harmonic frequencies than that obtainable with the frequency multiplier circuits of the prior art because of the flow of plate

15 current during a great portion of each cycle greatly lessening the flywheel requirements of the plate circuit to maintain the anode voltage during the remainder of each cycle. The operation of the circuit for cases where the harmonic $n=3$ or 5 is illustrated by the voltage-current curves of Figs. 5 and 6, respectively. In these figures, the curves show the varying control grid voltage e_g , the screen grid voltage e_s , the

20 plate voltage e_p and the plate current i_p plotted as ordinates against time as abscissae, the horizontal line labeled E_g , E_s and E_p on the three lower curves in each figure representing the fixed negative bias on the control grid, the fixed positive bias on the screen grid and the fixed plate

30 voltage on the plate of tube 1 of Fig. 1, respectively. The use of the suppressor grid 6 in the frequency multiplier tube of Fig. 1 provides greater efficiency in operation for the following reasons. As indicated in the curves of Figs. 5 and 6, the plate voltage e_p is low when the screen grid voltage e_s is high. Without the suppressor grid, this would tend to produce a large secondary

40 emission from the plate to the screen grid of the tube which would tend to oppose the desired plate current i_p and also might result in excessive screen grid dissipation. The suppressor grid operates to prevent this happening in the tube. The frequency multiplier circuit of Fig. 2 differs from that of Fig. 1 in the provision of means for

45 applying a modulating voltage to the suppressor grid 6 of tube 1, allowing the use of the tube as a combined frequency multiplier and modulator, and in the use of an alternative means for applying the fixed positive bias to the screen grid 5 from the plate circuit of the tube. As indicated, the modulation is applied between the

50 cathode 2 and suppressor grid 6 by transformer 18, and the suppressor grid 6 is negatively biased with respect to the cathode by battery 19. The fixed positive bias on the screen grid 5 of tube 1 in the circuit of Fig. 2 is obtained from the plate

55 battery 9 through a portion of coil 11 of resonant circuit 10 and the resistance 20 shunting the condenser 16.

60 The frequency multiplier circuit of Fig. 3 is similar to that of Fig. 1 but employs two pentode tubes 21 and 22 having their control grid-cathode

65 circuits and their cathode-anode circuits, respectively, connected in push-pull, instead of one tube as in the latter circuit, thus enabling a greater amount of harmonic power to be obtained, and also reducing the amount of fly-

70 wheel action needed. In the circuit of Fig. 3, equivalent negative biases are produced on the control grids of the two tubes 21 and 22 by the common grid battery 23 through the respective halves of the secondary

75 winding of input transformer 24. The primary

winding of transformer 24 is connected to a source of exciting voltage (not shown) of the base frequency f . A resonant circuit 25 comprising the inductance coil 26 and the variable condenser 27 in parallel, tuned to the desired harmonic frequency nf , is connected in series 5 between the plates of the tubes 21 and 22, and equivalent plate current is supplied to the plates of the two tubes from the common plate battery 28 through the equal upper and lower portions 10 of the coil 26, respectively. The suppressor grids of the tubes 21 and 22 are connected to a common point in the common heating circuit for the cathodes of the two tubes. The screen grids of tubes 21 and 22 are positively biased to the

15 same value by connections to a common tap on the common plate battery 28 through choke coils 29 and 30, respectively. Equivalent alternating voltages of the harmonic frequency nf are fed to the screen grids 20 of the tubes 21 and 22 from resonant circuit 85 from respective taps equally spaced from a midpoint on coil 26 of the resonant circuit 25, through condensers 31 and 32, respectively. A load circuit is connected to the output circuit of the

25 push-pull tubes through coil 33 inductively coupled to the coil 26 of the resonant circuit 25. The operation of the push-pull tube frequency multiplier circuit of Fig. 3 is similar to that of the single tube circuit of Fig. 1 or 2, but because of the push-pull connection a pulse of plate 30 current will be produced during every cycle of the harmonic frequency, and the harmonics produced in the common resonant circuit of the push-pull circuit will be odd harmonics whereas

35 either odd or even harmonics may be obtained in the single tube circuit of Fig. 1 or 2. Another frequency multiplier circuit employing two tubes is illustrated in Fig. 4. This circuit will provide a greater amount of harmonic power 40 than the single tube circuit of Fig. 1, as in the case of the circuit of Fig. 3, but will produce even harmonics in the resonant circuit in its output instead of odd harmonics as in the latter circuit.

The circuit of Fig. 4 differs from the circuit 45 of Fig. 3 in its output circuit only. The two pentode tubes 21 and 22 have their control grid-cathode circuits connected in push-pull as in Fig. 3, but the output circuit for the tubes is the same as in the case of a single tube circuit. 50 This is provided by connecting the plates of the two tubes 21 and 22 in parallel to one side of the resonant circuit 25 instead of to opposite sides as in Fig. 3, and also by connecting the screen grids of the two tubes in parallel to a 55 common point 33 on coil 26 of resonant circuit 25 through the condenser 34 instead of through separate condensers to different taps on coil 26 as in Fig. 3. In Fig. 4 the positive biasing current for the parallel-connected screen grids 60 of tubes 21 and 22, is obtained from a tap on the plate battery 28 through the single choke coil 35. These connections connect the load circuit associated with the output coil 23 effectively between the parallel-connected plates of 65 tubes 21 and 22 and the common cathode circuit, so that the harmonics appearing in the load circuit are even. The resonant circuit 25 in this case will be tuned to the desired even harmonic nf .

70 The voltage current curves of Fig. 7, similar to the curves of Figs. 5 and 6, illustrate the operation of the two-tube circuit of Fig. 4 for the case where the even harmonic $nf=4$. In the lower curves of Fig. 7 the solid curve labeled e_g 75

represents the control grid voltage of one tube and the dotted curve labeled e_{g2} represents the control grid voltage of the other tube in the circuit of Fig. 4. In the circuit of Fig. 4, as in the push-pull circuit of Fig. 3, only one of tubes 21, 22 is operative at one time. Therefore in the upper curves of Fig. 7, the solid line represents the plate current i_p for one of the two tubes of Fig. 4 for the first half of the cycle and the dotted curve the plate current i_p for the other tube during the last half of the cycle.

The two-tube circuits of Figs. 3 and 4 may be arranged to provide a common frequency multiplier and modulator in a manner similar to that illustrated for the single tube circuit of Fig. 2, in which case the modulation may be applied to the suppressor grids of the two push-pull tubes in parallel.

Various modifications of the circuits of the invention illustrated in the drawing and described above, which are within the spirit and scope of the invention will occur to persons skilled in the art.

What is claimed is:

1. A frequency changer circuit comprising an electron discharge device having a cathode, an anode, a control grid and a screen grid, and circuits therefor, means to impress an exciting voltage of a base frequency f on the control grid-cathode circuit, means to maintain said anode at a positive potential with respect to said cathode, said control grid being biased so that in response to the exciting voltage space current will flow in said device for a substantial portion of each cycle of the impressed frequency f , means for applying a fixed positive bias to said screen grid, the anode-cathode circuit of said device being tuned to a desired harmonic nf of said base frequency, means for superposing on the fixed positive bias applied to said screen grid a voltage of said harmonic frequency nf 180 degrees out of phase with respect to the anode voltage, and an output circuit coupled to said tuned anode-cathode circuit for taking off waves of said harmonic frequency.

2. A frequency multiplier comprising an electron discharge device having a cathode, an anode, a control grid, a screen grid and a suppressor grid, and circuits therefor, said suppressor grid being connected directly to said cathode, means maintaining said anode at a positive potential with respect to said cathode, means to impress an exciting voltage of a base frequency f on the control grid-cathode circuit of said device, said control grid being biased so that space current flows in said device during approximately 180 degrees of each cycle of the impressed voltage of base frequency f , a resonant circuit tuned to a desired harmonic nf of said base frequency, connected in the cathode-anode circuit of said device, means to apply a fixed positive bias to said screen grid, a capacitive connection from said resonant circuit to said screen grid for feeding thereto an alternating voltage of the frequency nf , 180 degrees out of phase with respect to the anode voltage, and a load circuit coupled to said resonant circuit for taking off a wave of the generated harmonic frequency.

3. A frequency changer comprising two vacuum tubes each having a cathode, an anode, a control grid, a screen grid, and a suppressor grid connected directly to said cathode, and circuits therefor, the control grid-cathode circuits and the anode-cathode circuits of the two tubes being respectively connected in push-pull, means maintaining the anode of each tube at a positive po-

tential with respect to the cathode thereof, means to impress a wave of a base frequency f symmetrically on the control grid-cathode circuits of the two tubes, a resonant circuit comprising an inductance coil shunted by a capacity, tuned to a desired odd harmonic nf of said base frequency f , connected in series between the anodes of the tubes so that equal but different portions of said inductance coil are included in the cathode-anode circuits of the respective tubes, means applying a fixed positive bias of the same value to the screen grids of said tubes, means to negatively bias the control grids of said tubes so that space current flows alternately through each tube for approximately 180 degrees of each cycle of the impressed wave of base frequency f , each of said screen grids being capacitively connected to points on said inductance coil so that an equivalent alternating current voltage of the harmonic frequency nf 180 degrees out of phase with respect to the anode voltage is impressed on each screen grid in superposition with the fixed positive bias thereon, and a load circuit coupled to said inductance coil for taking off the wave of harmonic frequency nf generated in said resonant circuit.

4. A frequency multiplier comprising two vacuum tubes each having a cathode, an anode, a control grid, a screen grid and a suppressor grid connected directly to said cathode, and circuits therefor, the control grid-cathode circuits of the two tubes being connected in push-pull relation, the anodes of the tubes being connected in parallel, the screen grids of the tubes being connected in parallel, a common source of space current connected between the cathodes and the parallel anodes of said tubes to maintain them at a positive potential with respect to the cathodes, means to apply a wave of base frequency f symmetrically to the control grid-cathode circuits of the two tubes, a resonant circuit comprising an inductance coil and a capacity, tuned to a desired even harmonic nf of said base frequency f connected in series between said parallel anodes and said source of space current, means applying a fixed positive bias to said screen grids, means to negatively bias the control grids of said tubes so that space current flows alternately through each tube for approximately 180 degrees of each cycle of the applied base frequency wave f , the parallel screen grids of said tubes being capacitively connected to the inductance coil of said resonant circuit so that an alternating voltage of said harmonic frequency nf 180 degrees out of phase with respect to the anode voltage is impressed on said screen grids in superposition with the fixed positive bias thereon and a load circuit coupled to said inductance coil for taking off from said resonant circuit, said desired even harmonic nf of said base frequency f .

5. A frequency changer comprising two vacuum tubes each having a cathode, an anode, a control grid, and a screen grid, and circuits therefor, the control grid-cathode circuits of the two tubes being connected in push-pull relation and the anode-cathode circuits thereof having a portion in common, means in said common portion of said cathode-anode circuits for maintaining the anodes of said tubes at substantially the same positive potential with respect to the cathodes thereof, means to impress a wave of a base frequency f symmetrically on the control grid-cathode circuits of the two tubes, a resonant circuit comprising inductance shunted by capacity, tuned to a desired harmonic nf of said base fre-

quency f , connected in said anode-cathode circuits of said tubes, means applying a fixed positive bias of substantially the same value to the screen grids of said tubes, the control grids of the two tubes being negatively biased so that a pulse of plate current will flow in said resonant circuit during substantially the whole cycle of the impressed frequency f , the screen grids of said tubes being capacitively connected to said reso-

nant circuit so that substantially equivalent alternating voltages of said harmonic frequency nf 180 degrees out of phase with respect to the anode voltage are impressed on the screen grids of said tubes in superposition with the fixed positive bias thereon, and a load circuit coupled to said resonant circuit for taking off the desired harmonic nf of the base frequency f generated therein. 5

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