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FREQUENCY MULTIPLIER

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FIG. 1

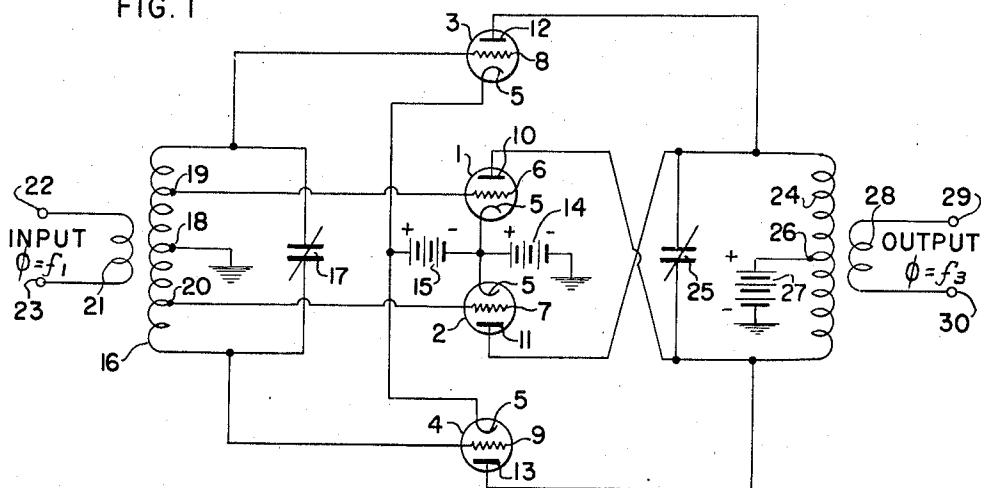
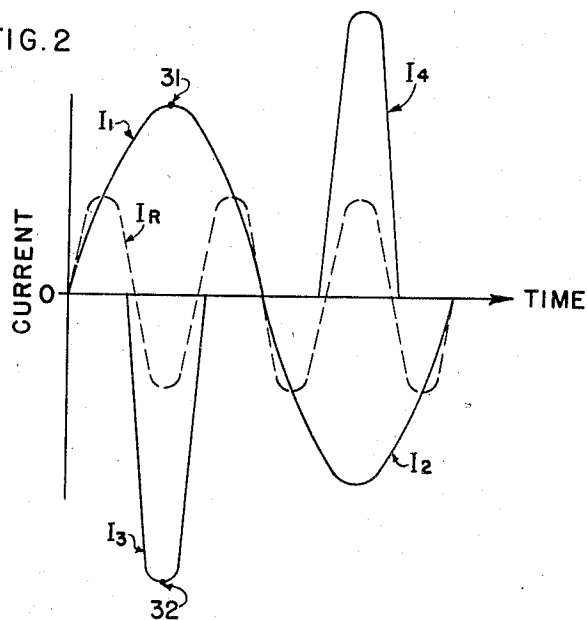


FIG. 2



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FREQUENCY MULTIPLIER

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This invention relates to frequency multipliers, and particularly to means for tripling high and ultra-high frequencies.

Frequency multiplier arrangements of the prior art have generally operated by utilizing the non-linear relation which exists between the grid voltage and plate current, or the non-linear relation between the grid voltage and grid current, of a vacuum tube to produce harmonics of the impressed signal. The output currents in such arrangements include components of the desired frequency or frequencies which are selected by suitable means, such as sharply tuned filters. Such methods of frequency multiplication are inherently inefficient, complicated and expensive and moreover are incapable of providing output signals of substantially the same wave form as that of the impressed signal.

The present invention is directed to the solution of the problem of providing frequency multiplication without the disadvantages of arrangements for this purpose heretofore provided.

The primary object of the present invention, therefore, is to provide an improved method of and means for effecting frequency multiplication characterized by simplicity and high efficiency.

In accordance with the present invention, there is provided a frequency multiplier which comprises first and second signal repeating means adapted to repeat relatively large portions and relatively small portions, respectively, of a signal impressed thereon. An output circuit for the repeating means is provided which combines the repeated signal portions in opposite phase to provide an output signal having an integral number of times the frequency of the input signal.

In one approved embodiment of the invention, the frequency multiplier comprises two pairs of similar multi-element vacuum tubes. The vacuum tubes of one pair are biased substantially to cut-off, and the vacuum tubes of the second pair are biased to several times cut-off. A portion of the voltage which is developed across a resonant circuit tuned to the frequency of the input signal is applied between the control electrodes of the first pair of vacuum tubes, and the total voltage developed across the input resonant circuit is applied between the control electrodes of the second pair. The output circuit includes a resonant circuit which is tuned to three times the frequency of the input signal. The terminals of this resonant circuit are connected directly to the output electrodes of one

pair of vacuum tubes, and with a reversed connection to the output electrodes of the other pair.

For a better understanding of the invention together with the other and further objects thereof, reference is made to the following description, taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the accompanying drawing:

Fig. 1 is a schematic circuit diagram of a frequency multiplier in accordance with the present invention; and Fig. 2 is a graph representing certain operating characteristics of the device of Fig. 1.

Referring now more particularly to Fig. 1 of the drawing, there is shown schematically a frequency tripler embodying the present invention in a preferred form. In general, the frequency tripler includes vacuum tubes 1, 2, 3 and 4 which are substantially identical. Each of tubes 1, 2, 3, 4 has a cathode 5 which may be of either the filament or indirect-heater type. Conventional means may be employed for heating cathodes 5, these means not being shown in the drawing to avoid unnecessary complication thereof. Tubes 1, 2, 3 and 4 also respectively include grids 6, 7, 8 and 9 which are substantially identical, but which are designated by different reference numerals for convenience in describing the operation of the system. Anodes 10, 11, 12 and 13 are provided for the tubes 1, 2, 3 and 4, respectively, and are also substantially identical but are designated by different reference numerals for convenience.

Cathodes 5 of vacuum tubes 1 and 2 are grounded through battery 14 connected with the polarity indicated in the drawing. Cathodes 5 of vacuum tubes 3 and 4 are connected to the positive terminal of battery 14 through battery 15 which has the polarity indicated in the drawing.

A parallel resonant circuit comprising an inductance element 16 and a condenser 17 is connected between grids 8 and 9 of vacuum tubes 3 and 4. Condenser 17 is preferably adjustable. The center tap 18 of inductor 16 is grounded. Grids 6 and 7 of vacuum tubes 1 and 2 are connected, respectively, to taps 19 and 20 of inductor 16. An input winding 21 is coupled to inductor 16 and connected to input terminals 22 and 23.

A parallel resonant circuit comprising an inductance element 24 and a condenser 25 is connected between anodes 12 and 13 of vacuum tubes

3 and 4 and, with a reversed connection, between anodes 10 and 11 of vacuum tubes 1 and 2. Condenser 25 is preferably adjustable. Center tap 26 of inductance element 24 is grounded through anode-supply battery 27, having the polarity indicated in the drawing. An output winding 28 is coupled to inductance element 24 and connected to output terminals 29 and 30.

The signal to be multiplied is applied to input terminals 22 and 23, and its frequency is designated in the drawing as f_1 . The output signal appears across output terminals 29 and 30, its frequency being designated in the drawing by f_3 .

The voltage of battery 14 is such that vacuum tubes 1 and 2 are biased substantially to cut-off, and the combined voltage of batteries 14 and 15 in series is such that vacuum tubes 3 and 4 are biased to several times cut-off. Resonant circuit 16—17 is tuned to the frequency f_1 of the input signal, and resonant circuit 24—25 is tuned to the frequency f_3 of the output signal.

The operation of the device of Fig. 1 may be readily understood by reference to the curves of Fig. 2. These curves are all plotted to the same time base, with the time increasing to the right, as indicated. Curve I₁ indicates the anode current of vacuum tube 1 which flows through inductance element 24 during the positive half-cycle swing of input signal voltage applied to grid 6 of this tube. Curve I₂ indicates the corresponding anode current of vacuum tube 2 during the half-cycle positive swing of the input signal voltage applied to its grid 7. It will be understood that, since vacuum tubes 1 and 2 are biased substantially to cut-off, anode current flows in each tube during only a half-cycle period of the input signal, and that, since the grids of the tubes are in phase opposition, when current is flowing in the anode circuit of one tube it is not flowing in the anode circuit of the other tube.

Curve I₃ indicates the anode current of vacuum tube 3 which flows through inductance element 24. Since this tube is biased by a voltage several times the bias voltage necessary for cut-off, anode current flows only during a relatively small portion of the positive half-cycle of input signal voltage applied to its grid 8. Although the voltage applied to grid 8 of vacuum tube 3 is in phase with the voltage applied to grid 6 of vacuum tube 1, the respective anode currents of these tubes through inductance element 24 are in phase opposition due to the reversed connections between resonant circuit 24—25 and vacuum tubes 1 and 2. Curve I₄ indicates the corresponding anode current of vacuum tube 4. The voltage applied to grid 9 of vacuum tube 4 is in phase opposition to that applied to grid 8 of vacuum tube 3, and therefore the current represented by curve I₄ flows in the opposite direction through inductance element 24 from that represented by the curve I₃.

Curve I_a represents the circulating current which flows in resonant circuit 24—25, and hence corresponds with the output signal of the tripler. It will be noted that the current represented by curve I_a has three times the frequency of the current represented by curve I₁ and I₂, which in turn corresponds in frequency with the input signal voltage.

In operation, a voltage of frequency f_1 is applied to input terminals 22 and 23 from any suitable source of excitation. Let it be assumed that, at a given instant, grid 6 of vacuum tube 1 is at the peak of its positive half-cycle. A resulting current flows in the anode circuit of tube 1, its peak value being indicated by the point 31 of

curve I₁. At the same instant, a voltage of the same phase but of greater amplitude is applied to grid 8 of vacuum tube 3, causing a current to flow in the anode circuit of tube 3, the amplitude of which is indicated by the point 32 of curve I₃. Due to the reversal of connections mentioned above, the anode current of tube 3 flows through inductance element 24 in a direction opposite to that in which the anode current of tube 1 flows. The flow of currents I₁ and I₃ through inductance element 24 causes the flow of a circulating current in resonant circuit 24—25 which is substantially equivalent to the resultant of currents I₁ and I₃ were they to be algebraically added, but the wave form of the circulating current is somewhat altered by the "fly-wheel" effect of resonant circuit 24—25 so that it closely approaches the sinusoidal wave form graphically represented in Fig. 2 by curve I_a. Since the negative peak value of the anode current of vacuum tube 3 occurs at the same instant as the maximum positive value of the anode current of vacuum tube 1, the resultant current indicated by curve I_a has three peaks for each single peak of the individual component currents, and hence the output current has three times the frequency of the current due to the input voltage. Vacuum tubes 2 and 4 function, respectively, in the same manner as vacuum tubes 1 and 3, except in the opposite phase, over the second half-cycle of the input signal voltage wave. The voltage induced in winding 28 and appearing between output terminals 29 and 30, therefore, has three times the frequency of the voltage impressed upon input terminals 22 and 23.

It will be understood that the relative amplitudes of the positive and negative swings of the resultant current I_a depend upon the amplitudes, respectively, of currents I₁ and I₃ (or of I₄ and I₂), and that the amplitudes of the individual anode currents in turn depend upon the signal voltage applied to grids 6 and 7 of vacuum tubes 1 and 2, compared with the signal voltage applied to grids 8 and 9 of vacuum tubes 3 and 4. Taps 19 and 20, therefore, are so positioned on inductor 16 that the positive and negative swings of the resultant current I_a are substantially equal.

It will be understood that vacuum tubes 1, 2, 3 and 4 of Fig. 1 may be replaced by a single pair of double triodes without departing from the scope of the present invention. If vacuum tubes 1 and 2 are replaced by a single double triode, and vacuum tubes 3 and 4 by a similar second tube, the double triodes may be of the type having a single cathode common to the two triode sections. If, however, vacuum tubes 1 and 3 are replaced by a single double triode, and vacuum tubes 2 and 4 by a second double triode, then the double triodes must be of the type wherein a separate cathode is provided for each triode section.

The frequency ranges in which the device of the present invention may be used are limited principally by the interelectrode capacitances of the vacuum tubes employed. No neutralization means are necessary for the stable operation of the device of the present invention. Experiments prove that the new device is practical and admirably suited for multiplying input signals having frequencies up to the order of 100 megacycles.

Whereas previous frequency multipliers of the grid-distortion type required an extremely high driving power and had anode-circuit efficiencies of only 20 to 30 percent, the device of the present invention requires relatively small driving

power and has a relatively high anode-circuit efficiency. This high efficiency is due to the fact that, whereas vacuum tubes 1 and 2 operate as ordinary class B amplifiers, vacuum tubes 3 and 4 operate as class C amplifiers under even more favorable conditions due to their smaller operating angle. Still greater efficiency may be realized by operating all four of the tubes in the class C region.

While there has been described what is at present considered the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A frequency multiplier comprising an input circuit adapted to have an input signal impressed thereon, first signal repeating means connected to said input circuit and adapted to repeat relatively large portions of said input signal, second signal repeating means connected to said input circuit and adapted to repeat relatively small portions of said input signal, and an output circuit for said repeating means for combining said repeated signal portions in opposite phase to produce an output signal having a frequency which is a multiple of the frequency of said input signal.

2. A frequency multiplier comprising an input circuit adapted to have an input signal impressed thereon, means for producing a small-amplitude signal and a large-amplitude signal corresponding in frequency to said input signal, first signal repeating means adapted to repeat relatively large portions of said small-amplitude signal, second signal repeating means adapted to repeat relatively small portions of said large-amplitude signal, and an output circuit for said repeating means for combining said repeated signal portions in opposite phase to produce an output signal having a frequency which is a multiple of the frequency of said input signal.

3. A frequency multiplier comprising an input circuit adapted to have an input signal impressed thereon, means for producing a small-amplitude signal and a large-amplitude signal corresponding in frequency to said input signal, first signal repeating means adapted to repeat substantially half-cycle portions of said small-amplitude signal, second signal repeating means adapted to repeat substantially smaller portions of said large-amplitude signal, and an output circuit for said repeating means for combining said repeated

signal portions in opposite phase to produce an output signal having a frequency which is a multiple of the frequency of said input signal.

4. A frequency multiplier comprising an input circuit adapted to have an input signal impressed thereon, means for producing a small-amplitude signal and a large-amplitude signal corresponding in frequency to said input signal, first signal repeating means adapted to repeat relatively large portions of said small-amplitude signal, second signal repeating means adapted to repeat relatively small portions of said large-amplitude signal, and an output circuit for said repeating means for combining said repeated signal portions in opposite phase to produce an output signal having a frequency which is a multiple of the frequency of said input signal, said first-mentioned means being so proportioned that the relative amplitudes of said small-amplitude and large-amplitude signals are such that the positive and negative swings of said output signal are substantially equal.

5. A frequency multiplier comprising an input circuit adapted to have an input signal impressed thereon, a first pair of amplifying vacuum tubes connected to said input circuit and so biased as to repeat relatively large portions of said input signal, a second pair of amplifying vacuum tubes connected to said input circuit and so biased as to repeat relatively small portions of said input signal, and an output circuit for said amplifying vacuum tubes for combining said repeated signal portions in opposite phase to produce an output signal having a frequency which is a multiple of the frequency of said input signal.

6. The method of multiplying the frequency of an alternating-current input signal which comprises the steps of repeating relatively large portions of said input signal, repeating relatively small portions of said input signal, and combining said repeated portions in opposite phase to produce an output signal having a frequency which is a multiple of the frequency of said input signal.

7. The method of multiplying the frequency of an alternating-current input signal which comprises the steps of producing a small-amplitude signal and a large-amplitude signal corresponding in frequency to said input signal, repeating relatively large portions of said small-amplitude signal, repeating relatively small portions of said large-amplitude signal, and combining said repeated portions in opposite phase to produce an output signal having a frequency which is a multiple of the frequency of said input signal.

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