May 14, 1940. W. ENGBERT 2,200,330

ULTRA SHORT WAVE FREQUENCY MULTIPLIER

Filed Oct. 21, 1938 2 Sheets-Sheet 1

Fig. 1

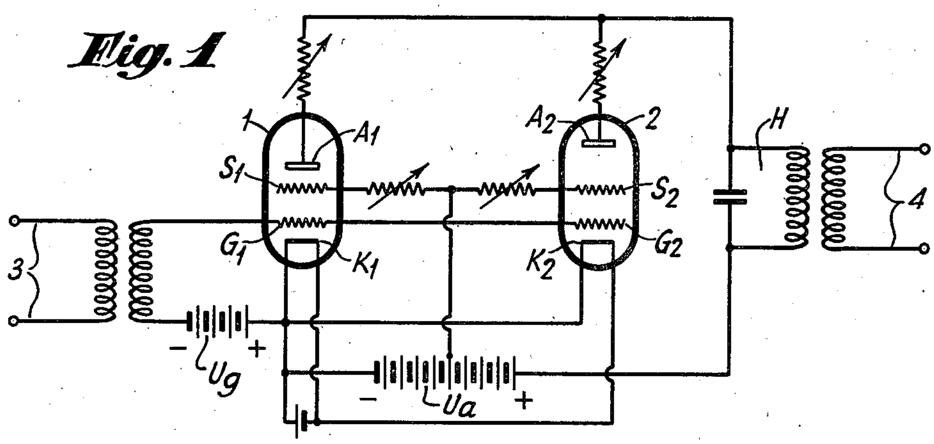

Fig. 2a

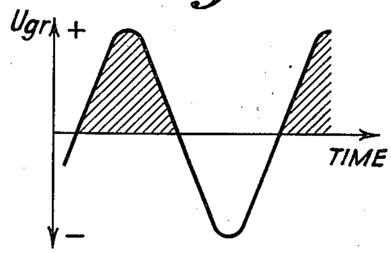

Fig. 2b

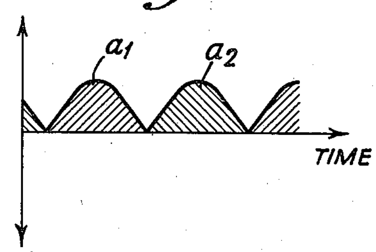

Fig. 3

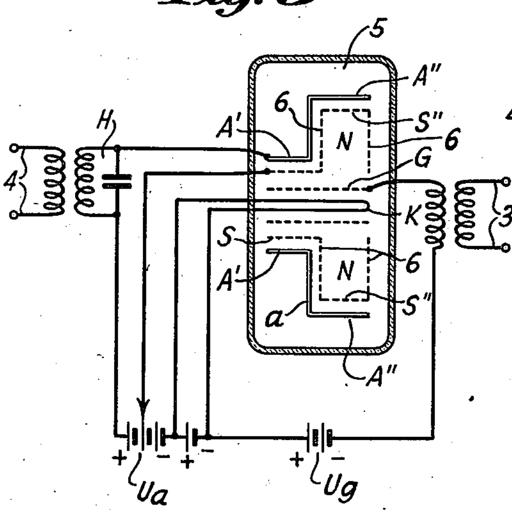

Fig. 4

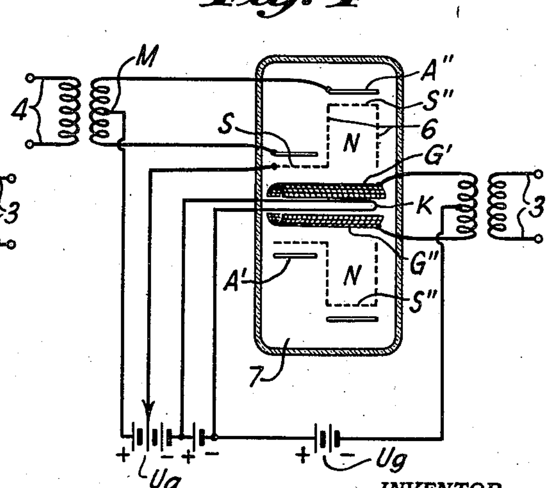

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Fig. 5

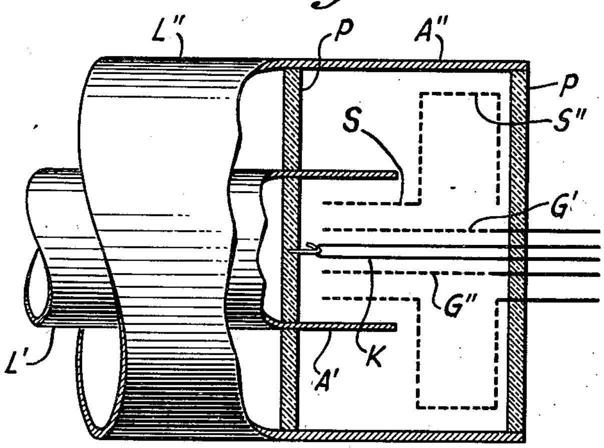
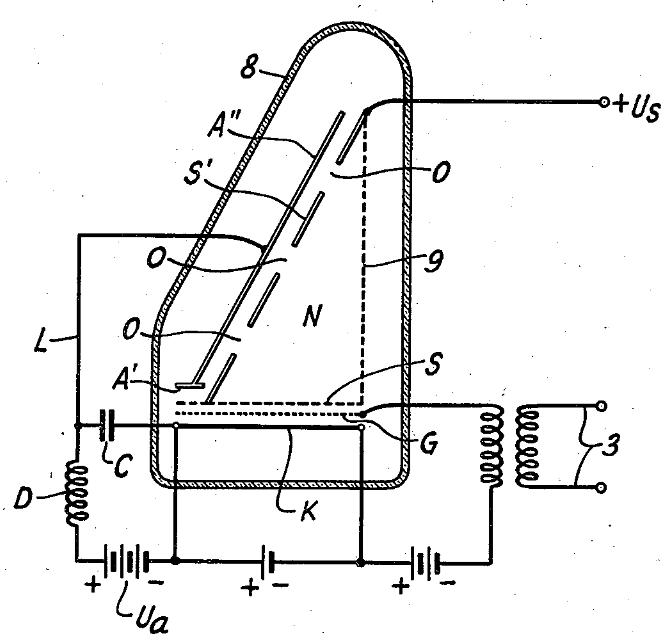


Fig. 6



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UNITED STATES PATENT OFFICE

2,200,330

ULTRA SHORT WAVE FREQUENCY MULTIPLIER

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Application October 21, 1938, Serial No. 236,147
In Germany November 4, 1937

8 Claims. (Cl. 250—36)

For the sake of frequency stability high frequencies are sometimes generated from lower fundamental frequencies by the process of frequency multiplication. What is generally used for the purpose is a tube whose control grid is impressed with the fundamental frequency, while in addition such a marked negative biasing potential is impressed on it that in the plate circuit which is preferably tuned to twice the fundamental, there arises the second harmonic of the latter. A demerit of this scheme is that the delivered oscillatory energy is low inasmuch as the plate circuit is fed with energy only every other alternation or half-cycle of the fundamental wave. The primary object of my invention is to overcome this drawback.

In carrying out my invention I preferably employ an electron discharge tube of special construction such that a plurality of electron discharge paths of unequal length are provided. These electron paths extend through spaces of constant potential gradients between the control grid and the anode. Hence it is possible to definitely fix the electron transit times along these paths separately. In fact, the transit times are so chosen that by one control impulse at least two current impulses are released, and these are caused to strike the anode or anodes at well defined time intervals. The discharge paths with different electron transit times may be accommodated inside separate vacuum vessels, or they may be disposed as independent electrode systems or assemblies inside one and the same envelope as is customary in the so-called multi-electrode tube.

My invention will now be described in full detail, reference being made to the accompanying drawings in which:

Figure 1 shows a circuit diagram illustrating how the fundamental idea of the invention is developed,

Figs. 2*a* and 2*b* are wave graphs which are referred to in explaining the theory of operation of the invention, and

Figs. 3 to 6 inclusive represent respectively different forms of construction of an electron discharge tube suitable for carrying out the invention.

Referring first to Fig. 1, I show therein a circuit arrangement comprising two separate discharge tubes 1 and 2. These tubes contain cathodes K_1 and K_2, control grids G_1 and G_2, screen grids S_1 and S_2 and anodes A_1 and A_2. The screen grids are used optionally.

Corresponding electrodes of these two tubes are connected in parallel relation to one another. It will be particularly noted that the space discharge path for the electrons in tube 1 is much shorter than the corresponding path in tube 2. The fundamental frequency oscillations which are to be multiplied are impressed upon the control grids from the input terminals 3. At the same time these same control grids are impressed from the source of potential U_g with such a high negative biasing voltage that only the positive peaks of the input alternating potential will permit a flow of plate current. The screen grids S_1, S_2 are impressed with a constant positive potential from a tap on the source of plate potential U_a. In the circuit of the paralleled anodes or plates A_1, A_2 is the output circuit H which most conveniently is tuned to the output or multiplied frequency. The multiplied frequency is taken off across the output terminals 4.

The theory of operation of this scheme will be best understood by reference to Figs. 2*a* and 2*b*. In Fig. 2*a* is plotted the input alternating potential U_g along the time axis. By virtue of the high negative bias applied to the control grids the flow of current is permitted only during the positive peaks of the control voltage. Fig. 2*b* shows the shape of the plate current, the plate current of tube 1 being designated by A_1 and the plate current of the tube 2 is designated by A_2. It will be noticed that the latter current starts only when A_1 has already dropped to zero again. This is obtained by making the transit time of the electrons in tube 2 longer by the length of an alternation of the fundamental wave. There are two ways in which the electron transit times in the tubes 1 and 2 may be differentiated. The distances between the control grid and the anode may be made different in the two tubes or the potentials applied to the screen grid and to the anode with respect to the cathode may be made different so as to increase the mean velocity of the electrons in one of the tubes over that in the other. If desired, both methods may be employed simultaneously.

In Fig. 1 is illustrated the case where the distance between the control grid G_2 and the plate A_2 is chosen substantially greater than the distance between A_1 and G_1. However, in addition also the potentials of the screen grids and the plates may be made of different value. Finally, where necessary, the advisability of choosing dissimilar control grid biasing potentials may be taken into consideration for compensation of differences in the openness of the mesh of the grid. If the slopes or mutual conductance values of the two discharge paths differ from each other, then the amplitude of the input alternating potential for the two tubes may be made different for the sake of compensation. Owing to a greater transit time required by the electrons of the tube 2 to cover the distance from the control grid to the anode, the current impulse occasioned by the same control potential impulse reaches the plate later than the simultaneously released plate impulse of the first tube. It will be noticed that in the common plate circuit, during each half cycle of the fundamental frequency, current is flowing and hence the power which becomes available in the oscillatory circuit H has been doubled compared to what it would be in a single tube. In case of a change of the fundamental frequency, the transit time difference may be suitably compensated by variation of the working voltages of one or of both tubes. Of course, it is also feasible to generate a higher harmonic of the fundamental wave by causing the current impulses to reach the plate at shorter intervals of time. In order to avoid overlapping of the constituent current pulses, the time during which the input potential swings the tube the full way must be correspondingly reduced. In other words, in case of frequency multiplication by factor n, the same should at most be made equal to the nth part of a full period of the fundamental wave. But this is readily attainable by sufficiently negative biasing of the control grids. The number of discharge paths, as will be noted, should be chosen preferably equal to the multiplication factor. The differences in the transit time are so chosen that the various impulses are fed to the plate circuit at a fixed periodicity. The control potential of the fundamental frequency may be fed to the control grids either from an oscillator resulting in a sinusoidal voltage wave or else they are distorted before being impressed thereon so that a more peaked potential curve results. The source furnishing the control potential could also consist of a multivibrator or a relaxation wave generator.

As above pointed out the different electrode systems may be assembled in a single tube envelope, if desired. Moreover, it is expedient to provide a constant potential gradient at least in the discharge path involving a greater transit time. A combination of these two steps is illustrated in Fig. 3.

The tube 5 contains an electrode assembly which presents cylindrical symmetry to the cathode K and which comprises the control grid G, the screen grid S and an anode consisting of two cylinders A′ and A″ of unequal diameters. The two parts of the anode are connected with each other inside the tube, say, by means of radial sheets or wires *a*. Co-ordinated with the anode A″ is another screen grid surface S″ which is united with the screen grid S by radially directed non-apertured or apertured metallic surfaces 6 so that these parts will enclose an annular space N whose boundary surfaces are at like potential. Electrons which enter into this space will thus continue their travel at the same rate of speed. For equal inter-electrode distances and potentials, as will thus be seen, such electrons as reach the anode A″ have a longer transit time than the electrons reaching anode A′, the disparity of time being approximately equal to the difference between the radii of the anode elements A′ and A″ respectively. Owing to the lateral boundary surfaces of the screen grid there is no appreciable flow of electrons from one discharge path to the other. The operation of this circuit organization as well as further details thereof are similar to those described in reference to Figs. 1 and 2.

A modification of such an arrangement in the form of a push-pull scheme is shown in Fig. 4. The vacuum tube 7 contains an electrode system built symmetrically about the cathode K and comprising two grid halves G′, G″ subject to push-pull control actions, two anodes A′, A″ which are in the form of cylinders of different diameters, and a unitary screen grid electrode S which is disposed inside the anodes A′ and A″. This electrode S embraces the screen grid surface S″, and the lateral surfaces 6 which flank an annular space N. The output circuit is connected to the two anodes A′ and A″, and its electrical center M is connected to the source of plate potential U_a. The output power is taken off across the terminals 4.

Where ultra-short waves are involved it is especially advantageous to feed the generated oscillations to the load by way of a concentric or coaxial type of cable or feeder line. To this end the anodes may be merged into and terminate in a tubular line such as schematically illustrated in Fig. 5. The electrodes are the same as in Fig. 4. The anode A″ forms part of the tube envelope and is closed at both ends by insulation disks P made of glass or ceramic material. The anode A′ is brought through one of the insulator disks P, while the rest of the electrodes are brought through the other insulation disk. From the right-hand side the operating potentials and the frequency to be multiplied are fed in, while the output feeder or coaxial line L′, L″ is led off from the left-hand side.

An exemplified embodiment of the invention which is particularly adapted to obtain a higher multiplication factor inside a single tube unit is schematically shown in Fig. 6. The tube 8 contains the cathode K and the control grid G which is impressed with the fundamental wave to be multiplied across input terminals 3. The screen grid S possesses its usual function. The anode A′ extends only over a small portion of the cathode K. Fitted thereto and connected therewith is a second anode A″ which diverges from the cathode. Placed parallel to this anode is an apertured screen electrode S′ having openings O, said screen electrode S′ being conductively associated with the screen grid S. It is expedient to enclose the space N within and by the electrodes S and S′ by means of a lateral electrode 9 which is conductively connected to S and S′ and is, therefore, carried at the same positive potential. The screen electrode S′ is made of sheet metal or else a close-meshed gauze and it is pervious to electrons only where there are openings O. The output circuit for ultra-short waves consists of a simple wire loop L which couples the anode to the cathode by way of a blocking condenser C. The anode potential U_a is suitably fed through a choke coil D.

As will be noticed this discharge device comprises four current paths of different lengths. One of these leads to the anode A′, while the others traverse the equipotential space N and terminate at the anode A′ through the three openings O. The negative control grid potential U_g in this instance should most suitably be so chosen that the control grid G permits the passage of maximum current during a quarter-period of the fundamental wave, that is to say, in the neighborhood of its positive peak value. If the potentials are conveniently chosen for the anode and the screen electrode, four current impulses will then consecutively reach the common anode circuit, and these will uniformly persist throughout duration of a complete period of the fundamental wave. If the fundamental oscillation, for example, has a wave length of 3.6 meters, then the wave arising in the plate circuit will have a length of .9 meter.

It will be clear that the design and construction of a tube as shown in Fig. 6 is capable of a great many modifications. For instance, a rotation-symmetric structure may be chosen whose axis is formed by the cathode, while the electrodes A'' and S' represent conical shells. The anode A', however, might also be dispensed with under certain circumstances in which case electron paths of dissimilar lengths will extend through the equipotential space N. Moreover, there may be a different number of openings O so that varying numbers of electron paths may be fixed. Under certain circumstances it may be advantageous to shield the various electron paths passing through their respective apertures O. This may be accomplished by the aid of parallel partitions or baffle walls mounted inside the equipotential space N in the neighborhood of the discharge paths. It is also feasible to concentrate or focus the electronic stream of the various discharge paths, and for this purpose recourse could be had to systems well known in the art of electron-optics, such as electric lenses, Wehnelt cylinders, and the like. Between the anodes and the screen grid surface adjacent thereto there may be mounted a suppressor grid as well known in the art, so as to prevent the flow of secondary electrons between these electrodes. On the other hand, recourse could be had to one or more stages of electron multiplication by means of secondary-electron emission, either as regards the fundamental frequency or else for the multiplied frequency, or both.

I claim:

1. A frequency multiplier system comprising an electron discharge device having means including suitably conformed electrodes for producing an electron discharge along a plurality of separate discharge paths, said discharge paths being of different lengths thereby to differentiate the electron transit times in a predetermined manner, means for impressing a fundamental frequency control potential upon said discharge device thereby to initiate pulses of electronic emission along said paths simultaneously, and means for deriving from said discharge device an alternating output current the frequency of which is that multiple of said fundamental frequency which accords with the variations in said electron transit times.

2. A system in accordance with claim 1 and having at least one cathode, control grids and anodes in said discharge device and means for biasing said control grids so strongly negative with respect to the cathode that said emissive pulses are initiated only during positive half waves of said control potential.

3. A frequency multiplier according to claim 1 and having said discharge device constituted by a single electron tube.

4. A frequency multiplier comprising an electron tube having grids and anodes symmetrically surrounding an axial cathode, said grids and anodes being arranged to provide a plurality of discrete electron discharge paths having different lengths, means supplying said grids and anodes with such constant potentials relative to the cathode as to produce electron transit times along each of the longer paths which are multiples of the transit time along the shortest path, and means including a source of fundamental frequency control potential applied between said cathode and the grids adjacent thereto for initiating emissive pulses along said paths.

5. A frequency multiplier according to claim 4 and having certain of said grids characterized as screen grids having cylindrical portions of unequal diameters and radial portions interconnecting said cylindrical portions.

6. In a frequency multiplier system having an electron discharge device characterized by the arrangement of its cathode, grid and anode electrodes in such manner as to provide a plurality of separate emission paths, the method of multiplying a high frequency input potential which comprises rendering said device conductive along said emission paths in response to positive half cycles of said input potential, and obtaining electron transit times along said paths such that clouds of electrons simultaneously released by said positive half cycles of input potential will travel along said paths and arrive progressively at said anode electrodes, the arrival times being at a harmonic frequency with respect to the frequency of said input potential.

7. A frequency multiplier system comprising an electron discharge tube for push-pull operation, said tube having an electrode structure presenting axial symmetry in reference to the cathode, said tube comprising a cathode, means including two similar control grids disposed on the two sides of said cathode and connected to a source of control potential for maintaining a push-pull control action on said tube at a fundamental oscillation frequency of said system, a screen grid, two anodes of different diameters, a second screen grid connected to the first screen grid and mounted anteriorly of the anode having the greater diameter, and means including an output circuit interconnecting said two anodes for deriving output energy of a frequency harmonically related to said fundamental oscillation frequency.

8. A frequency multiplier system in accordance with claim 7 wherein the two anodes of said discharge tube are extended outwardly therefrom and merged into two coaxial cylinders constituting an energy transmission system.

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